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Original research

# The prevalence of color vision deficiency in the northeast of Iran

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## Abstract

***Purpose***: To determine the prevalence of color vision deficiency (CVD) in the northeast of Iran.
***Methods***: This cross-sectional, population-based study was conducted in Mashhad, in the northeast of Iran. Multistage cluster sampling was used for selecting the participants. After preliminary screening, the subjects underwent a complete ophthalmic examination. The examination included the measurement of visual acuity, refraction, and slit-lamp biomicroscopy. The Farnsworth D-15 test was used to detect CVD. The color vision test was done with the best optical correction.
***Results***: Of the 4453 invitees, 3132 participated in the study (response rate: 70.4%). The overall prevalence of CVD in this study was 13.93% [95% confidence interval (CI): 12.44−15.41]. The prevalence of CVD in males and females was 15.85% (95% CI: 13.26−18.44) and 12.96% (95% CI: 11.22−14.71), respectively. The most prevalent types of CVD were tritanopia (6.96%; 95% CI: 5.84−8.08), deuteranopia (3.92%; 95% CI: 3.14−4.70) and tritanomalous (2.21%; 95% CI: 1.55−2.86), respectively. According to the results of logistic regression, the odds of having protanopia were higher in females than males [Odds ratio (OR) = 4.80; 95% CI: 1.20−19.18]. The odds of having deuteranopia were lower in females than males (OR = 0.52; 95% CI: 0.35−0.76). The odds of having CVD were lower in 16−30 (OR = 0.52; 95% CI: 0.37−0.73) and higher in 46−60 (OR: 1.41; 95% CI: 1.01−1.97) year age groups compared to 7−15 year age group. The odds of having tritanopia in 16−30 and 46−60 year age groups was 0.56 (95% CI: 0.35−0.90) and 1.79 (95% CI: 1.19−2.67) compared to 7−15 year age groups, respectively.
***Conclusion***: The prevalence of CVD was high in this study, especially in males and people over 46 years of age. Planning for involvement of ocular disease control programs in health care systems can be helpful in the reduction of CVD and improving the quality of life in affected patients.


*Keywords:* Color vision deficiency; Prevalence; Population based study; Farnworth D-15

## Introduction

Color vision deficiency (CVD) is one of the most important visual disorders affecting a considerable percentage of the population.[1] CVD may be congenital or acquired.[2,3] Congenital forms of CVD occur as a result of dysfunction in the cone cells, and the patient experiences different problems in

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detection and differentiation of colors depending on the type of the involved photoreceptor. Color blindness is classified into two main groups of red-green deficiency and blue-yellow deficiency according to the defective cone cells. Red-green deficiency in the most common type.[4,5] The acquired type of CVD has various subtypes caused by different diseases. The type of the defect depends on what part of the visual system, including the retina, optic nerve, and visual cortex, is affected by the disease or injury.[6,7]

The prevalence of congenital color blindness is different in various parts of the world. For example, 8% of men and 0.4% of women are color blind in western countries.[8] The prevalence of CVD is 4–6.5% in Japan and China,[2,3] 4% in African countries,[9] 7.3% in Turkey,[4] and 2.9–11% in Saudi Arabia.[10,11] However, the prevalence of acquired color blindness varies according to occupation, sex, and age, and has been reported to be 5–20% in different studies.[1,12–15]

Although no treatment has been found for this reason, some color lenses and gene therapy are available for the patients, but the results are not always satisfactory. For this reason, color blind people usually experience disorders in daily activities, learning, and skill acquisition for certain professions and therefore cannot have certain jobs.[16] As a result, they have a decreased quality of life and experience socioeconomic problems.[17]

Few studies have addressed the prevalence of CVD in Iran, and the available studies have covered different areas with different results. A study in Shahroud[1] reported a prevalence of 4.4% and 10.1% for congenital and acquired CVD, and other studies in Tehran,[18] the schools of Zanjan,[19] and the general population of Qazvin[20] reported a prevalence of 8.8%, 8.07%, and 3.49% for CVD, respectively, indicating differences in the prevalence of this disease in different parts of the country. Considering the importance of CVD, there is a need for comprehensive information on its status to make effective plans for it. Population-based studies can meet this need and provide health policy makers with a better perspective of this disease. Therefore, we conducted this study to evaluate the prevalence of CVD in Mashhad, the second largest city in Iran.

## Methods

This cross-sectional, population-based study was conducted in the urban population of Mashhad. The target population of the study was all residents of Mashhad aged above 1 year. The population of Mashhad was 2,451,712 according to a 2005 population census. Stratified cluster sampling was used to select the participants proportional to the population of different districts of Mashhad (municipality districts were considered as strata). A number of clusters were selected in each district proportional to the number of households. In total, 120 clusters were randomly selected from blocks determined by Statistics Center of Khorasan Razavi, and the first house number in each cluster was considered as the cluster head. In each cluster, sampling was systematically continued for up to 10 households. First, the interviewers introduced themselves, explained the importance of this project for the household, and completed a demographic questionnaire. Then they were invited to attend the Optometry Clinic of Mashhad University of Medical Sciences for complete ophthalmic examination. Sampling was systematically continued in a clockwise manner for up to 10 households. If a household was not willing to participate or was not present in the house, the next house number was invited. All participants were transported to the Clinic by the research team.

The Ethics Committee of Mashhad University of Medical Sciences approved the study protocol, which was conducted in accord with the tenets of the Declaration of Helsinki. All participants signed a written informed consent.

First, the uncorrected visual acuity was measured with an E Snellen chart. Then objective refraction was performed using an auto refractometer (TOPCON, KR-8000, Japan), and the results of auto refraction were refined with retinoscopy (HEINE BETA). In the next step, the best far and near optical correction was determined using subjective refraction, and near and distance best corrected visual acuity were recorded.

The Farnsworth D-15 test was used to assess color vision in all individuals aged over 7 years in similar light conditions with optical correction (near optical correction was used in presbyopic participants). The participants had only 5 min to finish the test. However, those aged above 50 years were given a little more time due to their increased reaction time.

Participants younger than 6 years of age, participants with a previous history of intraocular surgeries, and those who did not complete the color vision test were excluded from the study.

### *Statistical analysis*

In this study, the prevalence of CVD is reported as percentage along with 95% confidence interval (CI). In calculating CIs, we used binomial distribution when the distribution was not normal. The design effect was considered for the calculation of standard error. The effect of cluster sampling was regarded when calculating the CI. Simple and multiple logistic regressions were used to evaluate the relationship of CVD and its types with age and sex. A p-value of less than 0.05 was considered statistically significant.

## Results

Of the 4453 invitees, 3132 subjects participated in the study (response rate: 70.4%). After applying the exclusion criteria, eventually there were 2628 subjects available for this analysis. The mean age of the participants was 31.54 ± 16.9 years (range, 7–90 years), and 1751 of them (66.6%) were female.

The prevalence of CVD was 13.93% (95% CI: 12.44–15.41) in the study population, 15.85% (95% CI: 13.26–18.44) in men, and 12.96% (95% CI: 11.22–14.71) in women. Tritanopia was the most common type of CVD with a prevalence of 6.96% (95% CI: 5.84–8.08), followed by deuteranopia, and tritanomalous with a prevalence of 3.92% (95% CI: 3.14–4.70), and 2.21% (95% CI: 1.55–2.86), respectively.

According to the results of this study, the highest prevalence of CVD was observed in the age groups: over 60 years (20.93%; 95% CI: 13.63–28.23), 46–60 years (20.53%; 95% CI: 16.31–24.75), and 7–15 years (15.64%; 95% CI: 12.84–18.43), respectively. Regarding the type of CVD, tritanopia was the most prevalent type in all age groups. The prevalence of other types of CVD has been shown in Table 1.

Table 2 shows the results of simple and multiple logistic regressions for CVD and its types with respect to the age and sex. We considered the results of multiple model for interpretation of the data. According to this, the odds of protanopia in females were 4.80 (95% CI: 1.20–19.18) of its odds in males, while, the odds of deuteranopia were lower in females than males (0.52; 95% CI: 0.35–0.76).

By considering the 7–15 years age group as the reference group, the odds of having CVD in 16–30 and 46–60 year age groups were 0.52 (95% CI:0.37–0.73) and 1.41 (95% CI: 1.01–1.97), respectively. Also, the odds of having tritanopia in 16–30 year age group were lower than its odds in 7–15 year age group (0.56; 95% CI:0.35–0.90). The odds of having tritanopia in 46–60 year age group were higher than its odds in 7–15 year age group (1.79; 95% CI:1.19–2.67).

## Discussion

Congenital CVD is a common genetic disorder affecting many patients worldwide. Its hereditary type is a recessive X-linked disorder and is therefore more prevalent in men than women.[21] This disease causes a marked limitation and disability in the patients, and usually affects a considerable percentage of people depending on the population and its characteristics.[2–5,11,22–25]

The results of our study showed a prevalence of 13.93% for CVD in the study population, which is higher than other countries (Table 3). The prevalence of CVD has been reported to be 4.02% in Spain,[26] 7.33% in Turkey,[4] 10.3% in the USA,[27] and 2.56% in Italy.[23]

The findings of our study not only contradicted the notion that “the incidence of CVD is lower in Asian countries as compared with western countries”,[4] but also showed a higher prevalence in comparison with many Asian and Middle East countries. For example, the prevalence of CVD has been reported to be 5.28% in India,[7] 2.93% in Saudi Arabia,[10] and 8.72% in Jordan.[28] In addition to ethnic varieties, there may be 2 other reasons for this difference. The first reason could be the tool used for the assessment of color vision. The Ishihara's test was used in the studies conducted in Turkey,[4] Spain,[26] and Italy[23] while we used the Farnsworth D-15 test. The Farnsworth D-15 is the second most commonly used test for the detection of CVD after the Ishihara's test, and has a great capability for detecting CVDs, especially blue-yellow deficiency. Since the Ishihara's test can only detect red-green deficiency and cannot detect blue-yellow deficiency, some CVDs may be missed in studies that use the Ishihara's test, and therefore, their prevalence is underestimated.[29] The findings of our study are in line with the results of a study[1] that used the Farnsworth D-15 test and reported a prevalence of 14.7%.

The second reason for the high prevalence of CVD in our study could be cultural differences and the special conditions of Mashhad, as the second largest religious city in Iran. Although we did not investigate the effect of the consanguineous marriage on CVD, studies have shown increased odds in countries with a high rate of consanguineous marriages[30] or where there are closed communities, like Muslim communities[10,11] and Ashkenazi Jews.[31] It seems that Mashhad, as one of the most religious cities of Iran, has a similar condition leading to an increase in CVD. The differences between our study and the studies conducted in other parts of Iran confirm this hypothesis.[19,20,32,33]

Another finding of our study was the higher prevalence of CVD in men than women. The prevalence of color blindness was 15.85% in men and 12.96% in women. Although other studies have also reported a higher prevalence of the disease in men versus women,[1,23–28,31,33] the prevalence of color blindness in our female participants was higher than other studies. Although this finding is in line with the findings of study,[1] other previous studies have not supported this finding.[7,8,18–20,23–26,28,32,33]

There may be two reasons for the difference. The first is the test that was used to assess color vision. Most studies used the Ishihara's test, but[1] the ones whose results were similar to our study used the Farnsworth D-15 test. The second reason which is more important may be lack of differentiation between congenital and acquired cases in this study, causing overestimation in the prevalence of CVD.

Table 1
The prevalence (95% confidence interval) of color vision deficiency (CVD) and its different types in the study population by sex and age groups.

| | | Protanopia | Deuteranopia | Tritanopia | Protanomalous | Deuteranomalous | Tritanomalous | Color blindness |
|---|---|---|---|---|---|---|---|---|
| | | %(95%CI) | %(95%CI) | %(95%CI) | %(95%CI) | %(95%CI) | %(95%CI) | %(95%CI) |
| | Total (n = 2628) | 0.8(0.45–1.15) | 3.92(3.14–4.7) | 6.96(5.84–8.08) | 0.34(0.09–0.59) | 0.38(0.12–0.64) | 2.21(1.55–2.86) | 13.93(12.44–15.41) |
| Sex | Male (n = 877) | 0.23(0.06–0.91)[a] | 5.7(4.18–7.23) | 7.75(5.85–9.66) | 0.46(0.01–0.9) | 0.68(0.14–1.23) | 1.82(0.83–2.82) | 15.85(13.26–18.44) |
| | Female (n = 1751) | 1.09(0.6–1.57) | 3.03(2.21–3.84) | 6.57(5.22–7.91) | 0.29(0.1–0.81)[a] | 0.23(0.07–0.76)[a] | 2.4(1.66–3.14) | 12.96(11.22–14.71) |
| Age | 7–15 (n = 582) | 0.86(0.11–1.61) | 5.5(3.72–7.27) | 7.22(5.14–9.3) | 0.17(0.03–1.18)[a] | 1.03(0.08–1.98)[a] | 2.41(1.15–3.66) | 15.64(12.84–18.43) |
| | 16–30 (n = 773) | 0.26(0.06–1.04)[a] | 1.94(0.98–2.9) | 4.14(2.68–5.6) | 0.65(0.08–1.21) | 0.13(0.02–0.92) | 1.68(0.76–2.6) | 8.54(6.48–10.59) |
| | 31-45 (n = 691) | 0.72(0.09–1.36) | 4.63(3.06–6.2) | 5.64(3.82–7.46) | 0.14(0.02–1.03)[a] | 0 | 2.32(1.19–3.44) | 12.88(10.34–15.42) |
| | 46–60 (n = 453) | 1.55(0.43–2.66)[a] | 4.42(2.34–6.49) | 12.14(9.06–15.22) | 0.44(0.06–3.12)[a] | 0.44(0.11–1.78)[a] | 2.21(0.77–3.65) | 20.53(16.31–24.75) |
| | >60 (n = 129) | 1.55(0.39–6.15) | 3.1(0.18–6.03) | 11.63(5.88–17.38) | 0 | 0.78(0.11–5.45)[a] | 3.88(0.66–7.09) | 20.93(13.63–28.23) |

CI: Confidence interval.
[a] The 95%CI was calculated by binomial distribution.

Table 2
The association between color vision deficiency and its different types with age and sex by simple and multiple regressions logistic.

| | | | Protanopia | Deuteranopia | Tritanopia | Protanomalous | Deuteranomalous | Tritanomalous | Color blindness |
|---|---|---|---|---|---|---|---|---|---|
| | | | OR (95%CI); p-value | OR (95%CI); p-value | OR (95%CI); p-value | OR (95%CI); p-value | OR (95%CI); p-value | OR (95%CI); p-value | OR (95%CI); p-value |
| Simple regressions logistic | Sex | Female/Male | 4.8(1.2–19.18); 0.027 | 0.52(0.35–0.76); 0.001 | 0.84(0.6–1.17); 0.298 | 0.62(0.15–2.59); 0.516 | 0.33(0.08–1.41); 0.136 | 1.32(0.74–2.36); 0.345 | 0.79(0.62–1); 0.055 |
| | Age | 7–15 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | | 16–30 | 0.3(0.06–1.56); 0.151 | 0.34(0.19–0.62); 0 | 0.56(0.35–0.89); 0.014 | 3.78(0.46–31.35); 0.217 | 0.12(0.01–1.09); 0.06 | 0.69(0.32–1.52); 0.362 | 0.5(0.36–0.71); 0 |
| | | 31–45 | 0.84(0.24–2.94); 0.786 | 0.83(0.51–1.37); 0.472 | 0.77(0.51–1.15); 0.202 | 0.84(0.05–13.26); 0.903 | | 0.96(0.5–1.84); 0.906 | 0.8(0.6–1.05); 0.112 |
| | | 46–60 | 1.81(0.57–5.74); 0.313 | 0.79(0.43–1.47); 0.461 | 1.78(1.19–2.66); 0.005 | 2.58(0.17–40.12); 0.499 | 0.43(0.08–2.29); 0.319 | 0.92(0.4–2.07); 0.833 | 1.39(1–1.95); 0.052 |
| | | >60 | 1.82(0.35–9.43); 0.476 | 0.55(0.2–1.52); 0.249 | 1.69(0.89–3.22); 0.109 | | 0.75(0.09–6.55); 0.794 | 1.64(0.67–3.98); 0.277 | 1.43(0.88–2.31); 0.146 |
| Multiple regressions logistic | Sex | Female/Male | 5.73(1.49–22.13); 0.011 | 0.55(0.38–0.82); 0.003 | 0.93(0.66–1.32); 0.693 | 0.54(0.11–2.52); 0.43 | 0.47(0.11–2.07); 0.317 | 1.41(0.79–2.52); 0.246 | 0.87(0.69–1.11); 0.272 |
| | Age | 7–15 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | | 16–30 | 0.24(0.04–1.24); 0.088 | 0.39(0.21–0.7); 0.002 | 0.56(0.35–0.9); 0.015 | 4.33(0.53–35.42); 0.172 | 0.15(0.02–1.3); 0.085 | 0.65(0.3–1.43); 0.283 | 0.52(0.37–0.73); 0 |
| | | 31–45 | 0.68(0.19–2.4); 0.547 | 0.93(0.57–1.53); 0.784 | 0.78(0.52–1.17); 0.231 | 0.95(0.07–13.59); 0.969 | (empty)(–); | 0.91(0.47–1.75); 0.771 | 0.82(0.62–1.08); 0.158 |
| | | 46–60 | 1.65(0.52–5.29); 0.396 | 0.83(0.45–1.53); 0.55 | 1.79(1.19–2.67); 0.005 | 2.7(0.19–39); 0.465 | 0.45(0.08–2.57); 0.369 | 0.89(0.39–2.02); 0.787 | 1.41(1.01–1.97); 0.045 |
| | | >60 | 1.81(0.34–9.68); 0.486 | 0.55(0.2–1.51); 0.247 | 1.69(0.89–3.22); 0.109 | 0 | 0.75(0.09–6.54); 0.796 | 1.63(0.67–3.98); 0.279 | 1.43(0.88–2.31); 0.145 |

CI: Confidence interval; OR: Odds ratio.

The type of CVD depends on whether it is congenital or acquired. Red-green deficiency is more common in patients with congenital CVD,[4] and yellow-blue deficiency is more common in patients with acquired CVD.[1]

In our study, tritanopia was the most common type of CVD with a prevalence of 6.96%, followed by deuteranopia, and tritanomalous with a prevalence of 3.92%, and 2.21%, respectively. This order was also true for male and female participants. It seems that the higher prevalence of tritanopia in our study is due to the use of the Farnsworth D-15 test that can detect CVDs, especially blue-yellow deficiency.[29] Our results are in agreement with the findings of other studies[1,14,34] that used this test, and this can be a support for our justification.

The association between age and CVD was another finding of our study. The odds of having CVD were lower in 16–30 and higher in 46–60 year age groups compared to 7–15 year age group. It seems that the prevalence of CVD decreases until midlife and sharply increases thereafter. This pattern also holds for tritanopia. Individuals in older ages have a higher risk for developing ocular pathologies like cataract,[35] glaucoma,[36,37] retinal disorders,[38] systemic diseases (e.g., diabetes),[39] and more exposure to environmental factors which have influence on acquired color deficiency.[40–42] All of these increase the risk of acquired CVD. This issue can explain the observed associations in this study.

A strong point of our study is its large sample size as we evaluated about 2628 people. Therefore, our results are valid and have a high generalizability. Moreover, our sampling made it possible to include all age groups into the study to assess the relationship between age and the prevalence of CVD, which has been evaluated in a few studies.

Another strong point of this study is the use of the Farnsworth D-15 test instead of Ishihara's test, which enables us to explain our different findings, as well. In contrast to Ishihara's test that can only detect red-green deficiency, the Farnsworth D-15 can detect blue-yellow deficiency as well. This is especially important in the statistics of acquired CVD because most acquired cases have blue-yellow deficiency which may be missed on the Ishihara's test.

A limitation of this study is the lack of differentiation between acquired and congenital CVD, which may itself explain some differences with the results of previous studies. Some studies only reported the prevalence of congenital CVD and reported the prevalence of acquired and congenital CVD separately, which could lead to different results.

Another limitation of this report is that, we could not evaluate the association between some age-related ocular pathologies like cataract and glaucoma with CVD. The association between CVD and age may be due to the association between CVD and age-related ocular pathologies. Unfortunately, we were not able to explore such associations with the available data. Also, there may be other potential confounders that its effects have not been controlled in this study.

However, this study is very valuable due to its large sample size and population-based design, and its results can be used in health system policies.

Table 3
The prevalence of color vision deficiency (CVD) in different countries and other cities in Iran.

| Location | Age | Sample size | Type of color blindness | Screen test | Prevalence | | |
|---|---|---|---|---|---|---|---|
| In the World | | | | | Male% | Female% | Total% |
| Saudi Arabia, 1996[10] | 11–18 | 410 | congenital red-green color vision defects | Ishihara test | – | – | 2.93 |
| Turkey, 2002[4] | 20–26 | 941 | Congenital Color Blindness | Ishihara test | – | – | 7.33 |
| India, 2012[7] | – | 2674 | Congenital Color Blindness | Ishihara test | 8.73 | 1.69 | 5.28 |
| India, 2013[21] | 6–15 | 1028 | Color vision deficiency | Ishihara test | 11.36 | 3.03 | – |
| Philippines, 2010[6] | 12–16 | 1258 | Color vision deficiency | Ishihara and Farnsworth D-15 test | – | – | 5.17 |
| Nepal, 2012[43] | 19–26 | 215 | Color vision deficiency | Ishihara test | – | – | 5.58 |
| Nepal, 2012[16] | Medical student | 120 | congenital color vision defects | Ishihara test | – | – | 5.83 |
| Korea, 1989[24] | Middle school | 9438 | congenital color vision defects | Hardy-Rand-Rittler | 5.9 | 0.44 | 3.15 |
| Nepal, 2006[25] | 10–19 | 964 | Color vision deficiency | Ishihara test | 3.8 | 0 | 1.86 |
| Italy, 1992[23] | – | 3133 | red-green color vision defects | Ichikawa plates | 2.56 | 0.1 | 1.05 |
| Jordan, 2001[28] | university students | 1418 | congenital red/green color blindness | Ishihara test | 8.72 | 0.33 | 1.62 |
| America, 1985[27] | All ages | 2499 | Color vision deficiency | – | 20.4 | 1.8 | 10.8 |
| Spain, 1990[26] | student | 392 | red/green color blindness | Ishihara test | 4.02 | 0.46 | 2.04 |
| In The Iran | | | | | | | |
| Tehran, Iran, 2013[8] | 7–12 | 2160 | Color vision deficiency | Yang vision tester | 3.5 | 1 | 2.2 |
| Shahroud, Iran, 2013[1] | 40–64 | 5102 | Color vision deficiency | Farnsworth D-15 | 16.6 | 13.3 | 14.7 |
| Tehran, Iran, 1996[18] | 12–14 | 2058 | Color vision deficiency | Ishihara test | 4.51 | 0.19 | 4.71 |
| Zahedan, Iran, 2012[33] | primary school | 1000 | red/green color blindness | Ishihara test | 1.6 | 0.2 | 0.9 |
| Mashhad, Iran 2009 (current study) | All ages | 2628 | Color vision deficiency | Farnsworth D-15 | 15.85 | 12.96 | 13.93 |

In conclusion, the prevalence of CVD was high in Mashhad, especially in males and people over 46 years of age. Planning for involvement of ocular disease control programs in health care systems can be helpful in the reduction of CVD and improving the quality of life in affected patients.

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